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Original Communication

Foot index: Is it a tool for sex determination? ☆

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Abstract

Identification of an individual is of paramount importance in forensic investigations. The dimensions of the foot can be used for the determination of sex and stature of an individual in forensic investigations. No systematic studies are available on the determination of sex from foot measurements of North Indians. Therefore, foot index is derived to determine the sex of an individual in a single community of North India. The foot index for both genders is derived by dividing the foot breadth by foot length and multiplying it by hundred. In the present investigation, the foot index is found to be slightly higher in females in the right foot and males in the left foot. The study suggests that although foot length and foot breadth show significant sex differences, sex determination cannot be made conclusively from the foot index.

Keywords: Forensic science; Forensic anthropology; Physical anthropology; Foot index; Sex determination; North India; Identification

1. Introduction

Identification is the mainstay of any forensic investigation, whether it is of the suspect from the physical evidence at the crime scene or of the victim from dismembered, mutilated and charred remains. Identification of dismembered human remains has always been a challenge for forensic scientists. This problem is encountered in cases of mass disasters, explosion, and assault cases where body is dismembered to conceal the identity of the victim. When an individual foot is recovered and brought for examination, the dimensions of the foot can provide valuable information about the stature and sex of the person. Stature can be estimated from various measurements of the foot like foot length and breadth based on statistical equations and formulae.[1–5] Determination of sex is a critical requirement in identification, more so owing to different formulae for stature estimation in both sexes. Thus, sex determination from foot dimensions can immensely help the forensic scientists in identification of human remains.

Although extensive work has been carried out by different workers to estimate the stature from foot measurements,[1–5] small bones of the foot,[6] and foot prints,[7,8] a very few systematic studies are available on determination of sex from the foot dimensions. Researchers have, however, attempted sex determination from foot bones[9–12] and shape of the foot.[13] Telkka opined that each racial group will need a different formula, and region wise study of the subjects is very much needed as racial and ethnic variations arise in different regions.[14] Information on the determination of sex from foot dimensions in North Indians is presently inconclusive. The literature survey reveals that there is no conclusive agreement and systematic

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approach available on the determination of sex from foot measurements and so it was thought desirable to undertake the present investigation. In the present investigation an attempt has been made to find the sexual dimorphism of the foot index in a selected community using statistical considerations.

2. Materials and methods

This study is conducted on the people of Gujjar community residing in the villages of Patiala district of Punjab, North India. In the present investigation, length and breadth of both feet of hundred males and hundred females were measured to calculate the foot index that may be used for the determination of sex. Age of the subjects ranged from 18 to 80 years in males, and 18 to 65 years in females. Mean ± SD was 36.51 ± 15.87 years in males, and 32.19 ± 10.94 years in females.

The foot length of each individual is measured with a rod compass as a straight distance between the most backward point on the heel of the foot (pternion) and the most forward placed point on the longest toe of the foot (acropodian) when the foot is fully stretched. Breadth of the foot is measured perpendicular to the long axis with rod compass of the anthropometrical rod as a straight distance between the most laterally (metatarsale fibulare) and medially (metatarsale tibiale) placed point of the foot in a fully stretched position.

The foot index is calculated individually for both feet in males and females by using the formula: Foot index = (foot breadth/foot length) × 100. Study is carried out on a single community in order to minimize regional bias. The data obtained are computed and analyzed with SPSS (Statistical Package for Social Sciences, version 10.0) computer software and results drawn. Since the female data does not form a normal distribution we have applied a non-parametric test (Wilcoxon signed rank sum test). *p*-value <0.05 was considered significant.

3. Results and discussion

It is evident that in males, the length of the right foot ranges from 21.50 to 30.00 cm with a mean value of 26.28 cm, and the length of the left foot ranges from 23.20 to 29.80 cm, with a mean value of 26.31 cm. In females, the length of the right foot ranges from 21.10 to 28.10 cm with a mean value of 23.76 cm. The length of the left foot in females ranges from 21.30 to 28.10 cm with a mean value of 23.73 cm (Table 1). In males, the right foot breadth ranges from 8.50 to 11.90 cm with a mean value of 9.98 cm, while the left foot breadth ranges from 8.60 to 12.00 cm with a mean value of 10.13 cm. In females, the right foot breadth ranges from 8.00 to 10.40 cm with a mean value of 9.08 cm, and the left foot breadth ranges from 8.20 to 10.40 cm with mean value of 9.06 cm (Table 2). The foot length and foot breadth were significantly higher in males when compared to females for right and left feet ($p < 0.001$). The findings in our study with regard to foot length and breadth are in agreement with Ozden et al. who developed a formula to estimate the stature and sex of an individual using foot and shoe dimensions.[15] In our study, mean foot dimensions were dominant on the left side in males and on the right side in females. The difference between two sides was statistically insignificant for all dimensions except for foot breadth in males. Studies on right and left sided dominance in foot measurements are inconclusive. In the literature, dominant foot dimensions on the right side[1,2] and dominant left sided foot measurements[16,17] have been reported in males and females.

Table 1
Descriptive statistics: foot length (cm) in males and females

Gender	Male ($n = 100$)		Female ($n = 100$)	
	Right	Left	Right	Left
Minimum	21.50	23.20	21.10	21.30
Maximum	30.00	29.80	28.10	28.10
Mean	26.28	26.31	23.76	23.73
SD	01.59	01.54	01.10	01.11

SD, standard deviation ($p < 0.001$).

Table 2
Descriptive statistics: foot breadth (cm) in males and females

Gender	Male ($n = 100$)		Female ($n = 100$)	
	Right	Left	Right	Left
Minimum	08.50	08.60	08.00	08.20
Maximum	11.90	12.00	10.40	10.40
Mean	09.98	10.13	09.08	09.06
SD	00.69	00.67	00.49	00.49

SD, standard deviation ($p < 0.001$).

In males, the foot index ranges from 33.07 to 44.03 in the right and 33.21 to 45.80 in the left foot, respectively. The mean foot index in males was 38.01 and 38.55 for right and left foot, respectively. The foot index in females ranges from 33.85 to 43.86 in right foot, and 33.73 to 43.04 in left foot. The mean foot index for right and left foot in females was 38.26 and 38.21, respectively (Table 3). The foot index has been observed to be more on the left side in males, and on the right side in females. Statistically significant differences between the two sides have been found in foot index in males.

In the present investigation, the foot index has been found to be higher in females in the right foot and lower in the left foot when compared to males. Mean foot length, foot breadth and foot index values calculated for different age groups for both genders are shown in Tables 4 and 5. No statistically significant differences were found in foot index between males and females ($p > 0.05$). Distribution of foot index in males and females for right and left foot is shown in Figs. 1 and 2. Our findings are contrary to earlier studies[17,18] that calculated foot index from mean foot dimensions in different age groups and derived 37.00 as the deviation point for foot index in sex determination. In both studies, however, neither the statistical significance

Table 3
Descriptive statistics: foot index in males and females

Gender	Male ($n = 100$)		Female ($n = 100$)	
	Right	Left	Right	Left
Minimum	33.07	33.21	33.85	33.73
Maximum	44.03	45.80	43.86	43.04
Mean	38.01	38.55	38.26	38.22
SD	02.17	02.32	02.03	02.07

SD, standard deviation ($p > 0.05$).

of foot index as a sex determinant nor percentage accuracy and distribution of foot index are shown.

It is concluded that the foot index cannot be used to determine sex although from the present study shows that there are statistically significant sex differences in foot measurements. Studies on a larger sample are, however, proposed to confirm the findings of our study. Foot index needs to be explored further with respect to sample size, different populations, profession, and environment.

Table 4
Mean foot dimensions and foot index among the males ($n = 100$) in different age groups

Age (years)	Right foot			Left foot		
	Length	Breadth	Foot index	Length	Breadth	Foot index
18–25	25.93	09.92	38.33	25.87	10.01	38.78
25–30	26.07	10.09	38.71	26.24	10.29	39.24
30–35	27.62	10.43	37.79	27.52	10.66	38.75
35–40	25.36	09.60	37.91	25.46	09.73	38.23
40–45	26.81	10.08	37.61	26.93	10.28	38.20
>45	26.43	09.93	37.57	26.54	10.12	38.15

Table 5
Mean foot dimensions and foot index among the females ($n = 100$) in different age groups

Age (years)	Right foot			Left foot		
	Length	Breadth	Foot index	Length	Breadth	Foot index
18–25	23.57	08.91	37.86	23.51	08.91	37.96
25–30	24.07	09.18	38.17	23.99	09.15	38.18
30–35	23.75	09.06	38.21	23.68	08.94	37.80
35–40	23.93	09.30	38.91	23.94	09.28	38.90
40–45	23.47	09.02	38.42	23.23	08.95	38.53
>45	23.80	09.24	38.85	24.12	09.32	38.65

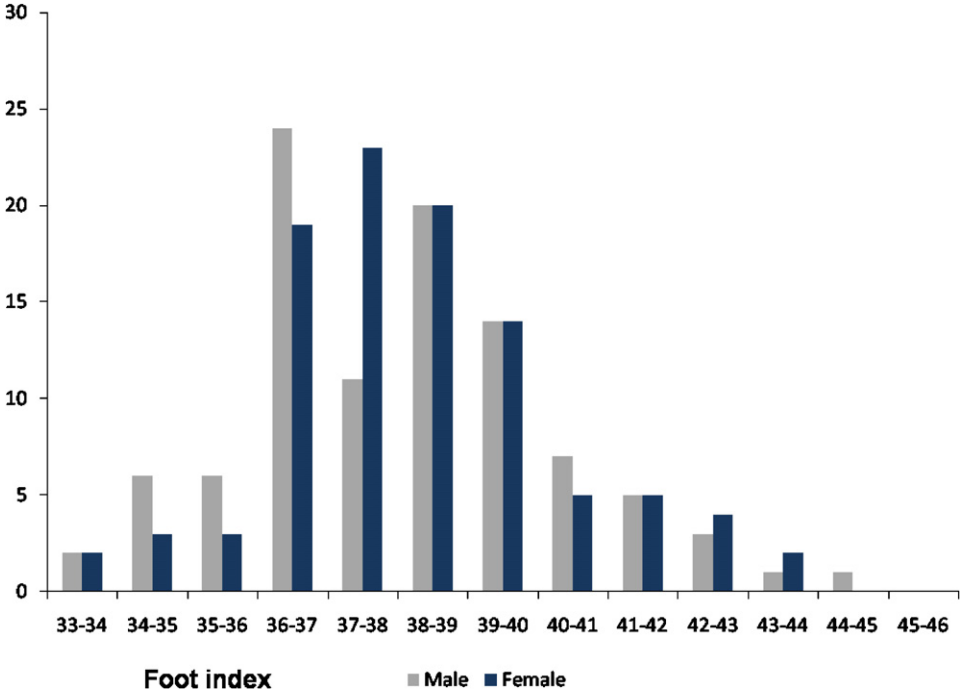

Fig. 1. Right foot index – distribution of cases.

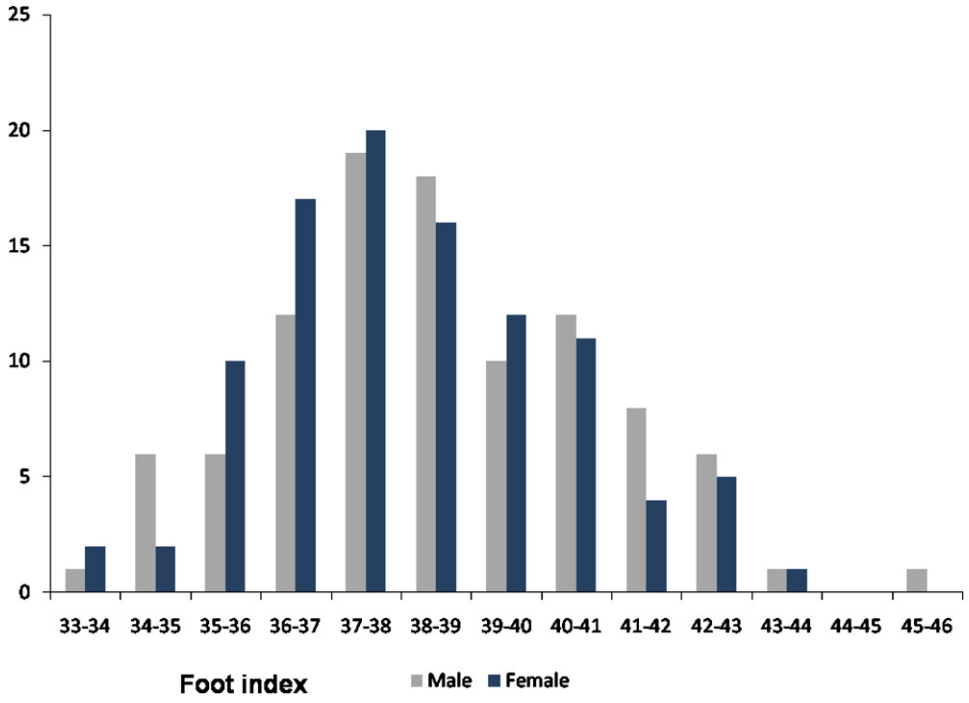

Fig. 2. Left foot index – distribution of cases.

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